World Housing Encyclopedia

an Encyclopedia of Housing Construction in Seismically Active Areas of the World

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HOUSING REPORT
Concrete Shear Wall Buildings

Report #	4
Report Date	05-06-2002
Country	CHILE
Housing Type	RC Structural Wall Building
Housing Sub-Type	Reinforced Concrete Structural Wall Building : Moment frame with in-situ shear walls
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Important

Summary

This housing type is mainly characterized by reinforced concrete shear walls that are built in both directions along the entire eight. Some of the walls may be perforated with openings (coupled walls). These buildings are multiple housing units and are found in the major urban areas in Chile. Stiffness and mass distribution are regular and most of them may have a symmetry axis in at least one direction of the plan. In general, these buildings are quite stiff because they must resist a base shear of 5#6.7% (depending on the seismic zone) and the story drift must be equal to or less than 0.002. Seismic performance is very good, strength and stiffness are controlled, and torsional effects are minimal. The buildings may have one or two basement floors. problems that may appear in the future include reduction in the wall density, introduction of soft floor, or torsional effects.

1. General Information

Buildings of this construction type can be found in This type exists in all main cities of the country: Iquique, Antofagasta, Concepción, Temuco, Valparaíso, Viña del Mar and Santiago. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 50 years ago. Currently, this type of construction is being practiced. .

Figure 1: Typical building

2. Architectural Aspects

2.1 Siting

Such constructions are typically found in flat, sloped and hilly terrains. Such buildings do no have common walls with adjacent buildings. When separated from adjacent buildings, the distance from adjacent building is generally 10 meters.

2.2 Building Configuration

Not Applicable. In this country there is no standardization for any element: window, door, etc, so it is not possible to provide an estimate of number or size of openings.

2.3 Functional Planning

The main function of buildings of this type is multi-family housing. In a typical building of this type, there are no elevators and 1-2 fire protected exit staircases. Modern buildings have pressurized stairs and the taller ones also have a helicopter landing strip on the top.

2.4 Modification to Building

Rectangular.

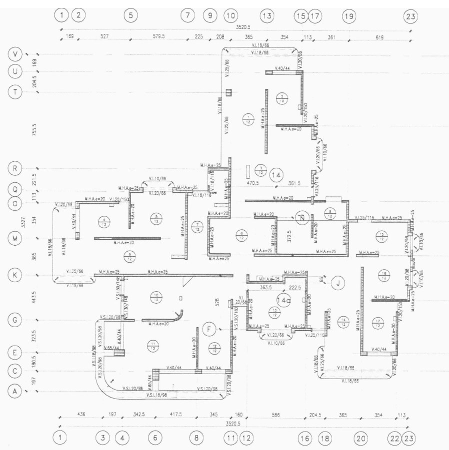

Figure 2A: Plan of a typical building

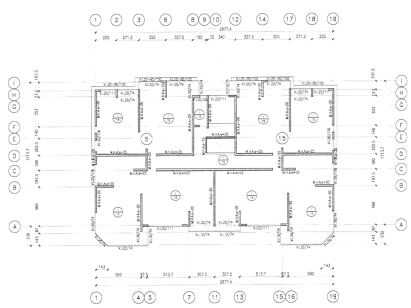

Figure 2B: Plan of a typical building

3. Structural Details

3.1 Structural System

This is a RC Structural Wall Building and Reinforced Concrete Structural Wall Building : Moment frame with in-situ shear walls.

3.2 Gravity Load-Resisting System

The vertical load resisting system is Shear walls act as lateral as well as gravity load-bearing elements. Beams and slabs carry floor loads.

3.3 Lateral Load-Resisting System

Shear walls provide adequate strength and stiffness to control lateral displacements. In some cases, lintel beams couple some walls, thus resulting in the reduced lateral displacements. If designed and detailed properly, those coupling beams dissipate energy when subjected to

severe earthquakes and are easily repaired after an earthquake.

3.4 Building Dimensions

The length of the building is 20 m and width 20 m. The building has 4 to 30 storey(s). The typical span of the roofing/flooring system is 6 meters. Typical Plan Dimension: Average area are: 487 m². Typical Number of Stories: In recent years the average is 13 stories. Typical Story Height: Variation of story Height is 2.6 m - 2.8 m. Typial Span: It is on average. Usually span is limited to 4 m - 8 m. The typical storey height in such buildings is 2.7 meters. The typical structural wall density is less than 3 %. Total wall area/plan area (for each floor) For the 95% of the buildings, the wall density is greater than 1.5% in each direction, average value = 2.8% Figure 5A shows the variation on time of the wall density which has remain almost constant.

3.5 Floor and Roof System

Solid Slabs (Cast in place) Post Tensioned Slabs. The floors and the roof are considered rigid in seismic analysis. Post-tensioned slab are used less often than cast in place, but there are some buildings designed by important engineers firm that do have it. VSL has an office in Chile and they are trying to introduce it.

3.6 Foundation

The building has a shallow foundation. The shallow foundation is a reinforced concrete strip footing and mat foundation. Strip footings are used in firm soil for middle height buildings (6-10 stories), but in softer soils or when there are basement for parking mat footings are used.

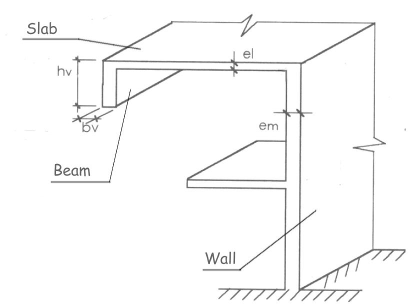

Figure 3: Key load-bearing elements

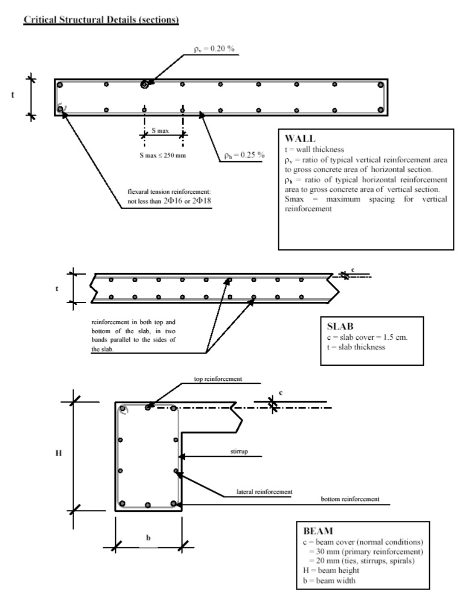

Figure 4: Typical wall section, slab and beam

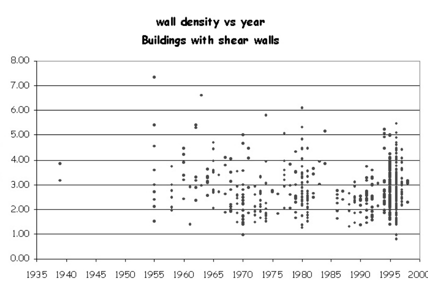

Figure 5A: Wall density: a key seismic feature

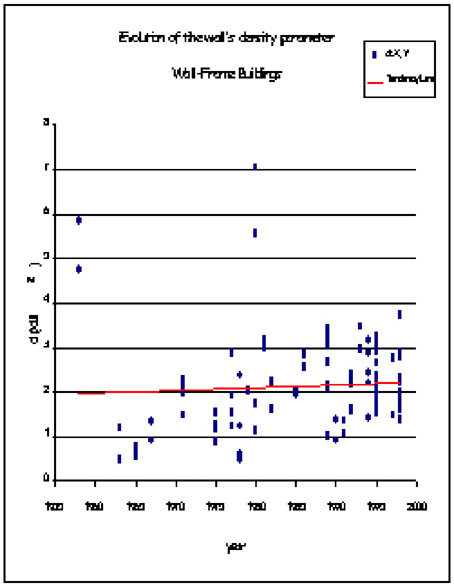

Figure 5B: Wall density

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each such building has 51-100 housing unit(s) in it70 units in each building. The number of inhabitants in a building during the day or business hours is more than 20 persons. Similarly, the number of inhabitants during the evening and night is more than 20 persons. During the day the inhabitants may be one fourth of those that reside in the night. Each unit may have 4-8 inhabitants.

4.2 Patterns of Occupancy

One family occupies one housing unit.

4.3 Economic Level of Inhabitants

Persons living in the housing are middle class and rich. The prices are expressed in US$. In Chile the income is very non-uniformly distributed, and the rich constitute less than 10% of the population. Middle class apartments may cost 1500-4000 UF (US$37.500-100.000), and the annual income for a family of 4 people may be US$ 20.000 Larger apartments may cost 7000-10.000 UF (US$ 175.000-250.000), and the annual income for a family of 4 people may be US$ 120.000 Economic Level: For Middle Class the Housing Price Unit is 50000 and the Annual Income is 20000. For Rich Class the Housing Price Unit is 250000 and the Annual Income is 120000. The ratio of the Housing Unit Price to their Annual Income is 3:1. The typical source of financing the purchase of a housing unit in these buildings is owner finance, personal savings , loans from commercial banks / mortgages and investment pools. In each housing unit, there are 1 bathrooms (with no toilets), 0 toilets only and 0 bathrooms-cum-toilets.

4.4 Ownership

The type of ownership or occupancy is renting, ownership with debt (mortgage or other) and individual ownership.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

The structure contains a complete load path for seismic force effects in any horizontal direction that serves to transfer inertial forces from the upper portions of the building to its foundation. The building is regular with regards to its plan and elevation. The roof diaphragm is rigid and is expected to maintain its integrity, i.e., shape and form, during an earthquake of intensity expected in the area where the building is located. The floor diaphragm(s) are rigid and are expected to maintain their integrity, during an earthquake of intensity expected in the area where the building is located. There is no evidence of excessive foundation movement (e.g., settlement) that would affect the integrity or performance of the building in an earthquake. At least two walls or frames are available in each principal orthogonal direction of the building structure. At each storey level, the height-to-thickness ratio of shear walls is well maintained; the standard is <635mm (25 in) in reinforced concrete walls, <760 mm (30 in) in reinforced masonry walls, and <330 mm (13 in) unreinforced masonry walls. Vertical load-bearing elements (e.g., columns and walls) are doweled into the foundation. No information is available on anchoring of the exterior walls into roof and every floor with metal anchors or straps for out-of-plane seismic effects. No information is available on the total width of door and window openings in a wall; the standard is <1/2 the distance between adjacent cross walls in brick masonry walls in cement mortar, <1/3 the distance between adjacent cross walls in adobe masonry, stone masonry & brick masonry in mud mortar, and 3/4 the length of perimeter wall in precast concrete walls. Quality of building materials is adequate as per requirements of relevant national codes and standards. Quality of workmanship (based on visual inspection of few typical buildings) is as per relevant national codes and standards. Buildings of this type are generally well maintained and there are no visible signs of deterioration of building materials (e.g., concrete, steel and wood).

5.2 Seismic Features

Structural Element	**Seismic Deficiency**	**Earthquake Resillient Features**	**Earthquake Damage Patterns**
Wall	none	High wall density, regular on height lead to story drift under control, negligible P-D effect, less sensible to non-structural elements, plasticity uniformly distributed. In case of damage are easily repaired	Small Shear Cracks
Frame (columns, beams)			

Roof and floors	Some damage has been reported in slab with openings, i.e. between stairs and elevators, when there are not lintels and the slab works as a coupling element and no special reinforcements have been provided.		Shear Crack in Intels

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *F: VERY LOW (i.e., excellent seismic performance)*, the lower bound (i.e., the best possible) is E: LOW (i.e., very good seismic performance), and the upper bound (i.e., the worst possible) is *F: VERY LOW (i.e., excellent seismic performance)*.

5.4 History of Past earthquakes

Year	Epicenter	Magnitude	Intensity
1960	Valdivia, X Region	9.5	XI-MMI
1985	Liolleo	7.8	VIII

Not many buildings existed in southern Chile in 1960, the only damage cited in the literature is the hospital in Valdivia. In 1985 only one building partially collapsed in Santiago (Villa Olímpica) and one had to be demolished in Viña del Mar (El Faro de Reñaca). Important damages occurred in 5 stories buildings (Canal Beagle) that were located on the top of a hill in Viña del Mar where important acceleration amplification have been measured. A few others buildings in Viña del Mar had some walls damaged and some others had non-structural damage. FIGURE 6 shows the Edificio Acapulco building in Viña del Mar, after the 1985 Llolleo earthquake. This building suffered some damage in lintels during 1971 earthquake, that was not properly repaired, so during 1985 new cracks appeared.

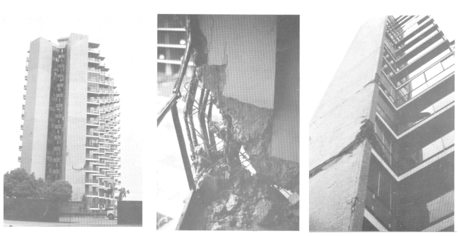

Figure 6: Edificio Acapulco, Vina del Mar, 1985 Llolleo earthquake

6. Construction

6.1 Building Materials

Walls: Reinforced Concrete H25-H35 steel. 1.5-4.0/25-35/1.5-2.0 A63-42H or A44-28H. 1.5-4.0/25-35/1.5-2.0 A63-42H or A44-28H. st/f'c/shear strength (1) sand: cement:

water (2).

Roof and Floor(s): Reinforced concrete. H25-H30.
Notes: 1. The values that appear in column characteristic strength are : Tension/compression/ shear strength. The Chilean denomination is H25- H35. Denomination for concrete: H35 (10) 20/10 means a concrete with a 28-days cubic compressive strength of 35 MPa, with 10% of defective fraction, nominal size of coarse aggregate not larger than 20 mm and with slump of 10 cm. Steel A63-42H means maximum tension strength of 630 MPa and yield strength of 420 MPa. 2. Mix proportions are: sand: cement: water.

6.2 Builder

It is built by developers and sold to the people who will live in this construction type.

6.3 Construction Process, Problems and Phasing

Yes, of course they play a role as is explained in Building Expertise.

6.4 Design and Construction Expertise

The structural engineer will have 6 years of studies and more than 3-5 years of experience. The construction engineer may have 6 years of studies and less experience than the structural engineer. There is no compulsory inspection during the construction and no peer revision of the structural project. The designer may visit the construction site one or two times during the construction.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the countryNCh433.of96 Seismic Design of Buildings Year the first code/standard addressing this type of construction issued: Until 1993 the NCh433.of72 was in force. The last two numbers indicates the year since the code is in force. Provisionally dispositions to design this type of buildings existed since 1966. National building code, material codes and seismic codes/standards: NCh433. of96. In addition, ACI318-95 is used for design reinforced concrete elements, with some exceptions: the minimum compressive strength is 16 MPa, confinements at wall end or diagonal bars in couple beam are rarely used and a reduced reinforcement cover is allowed. The appendix of the NCh433.of96 states that "the shear wall design doesn't need to follow dispositions 21.6.6.1 to 21.6.6.4 of ACI 318-95. When was the most recent code/standard addressing this construction type issued? 1996.

The building design must follow the NCh433.of96 code, although no one verifies. In case of damage an arbitrage process may take place at the court of justice.

6.6 Building Permits and Development Control Rules

This type of construction is not an informal construction. This type of construction is not authorized as per development control rules. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s) and Renter(s).

6.8 Construction Economics

A unit construction may cost 15-35 UF/ m^2 (500-1200 US$/$m^2$). Nowadays the progress in construction is quite rapid, probably one or two floors per month.

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened exising buildings or new buildings built to incorporate seismically resillient features, an insurance premium discount or more complete coverage is not available. Earthquake insurance is available as an additional to insurance against fire. In this case the premium cost is almost doubled. In case of damage this insurance will cover repair work.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Lintels damage	Rebuilt the lintel or fixed with epoxy.
Shear cracks in walls	The wall is thickened with a new mesh or confined element are added at the extremes.

This is not a common activity in Chile. FIGURES 7A and 7B show strengthening of earthquake damaged building shown on FIGURE 6. Columns have been added to the extreme of one wall.

8.2 Seismic Strengthening Adopted

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
Only after an earthquake some buildings have been repaired, when some constructive deficiencies appeared. Edificio Acapulco in Viña del Mar, suffered some damage in lintels during 1971 earthquake, that were not properly repaired, so during 1985 new cracks appeared. FIGURES 6 and 7A show the Acapulco building after the 1985 earthquake and after repaired work was done.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?
Probably not.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was

an architect or engineer involved?
A contractor and an engineer were involved hired by the owner/user.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
No earthquakes have occured in Central Chile since 1985.

Figure 7A: Seismic strengthening (Edificio Acapulco building damaged in the 1985 Llolleo earthquake). A column has been added to the wall exterior.

Figure 7B: Seismic strengthening (Edificio Acapulco building). The exterior wall has been thickened with a new steel mesh.

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